A small step towards making the national capital region safer from seismic hazard and risk

The NCR (National Capital Region) currently shows low level seismicity. However, according to the historical information, the region has faced two very large events, viz. the MMI XII (?) event in 893 (ref. 1) and the 1720 (ref. 2) event of MMI XI. Even relatively distant events have inflicted damage in Delhi[3–5]. This obviously sets up serious alarm regarding seismic hazard of the region. A repeat of the 1720 event now could be as calamitous, if not more than the 2001 Bhuj event.

The calamitous, M 7.7, Gujarat earthquake of 26 January 2001 occurred in a region of low seismic activity. Thus a relatively low rate of small earthquakes does not necessarily equate to low seismic hazard.

Let us consider the seismic risk in NCR. Seismic risk consists of exposure and vulnerability of population, infrastructure and economy of the region. A population of about one crore is exposed to hazard in NCR. There is large proportion of old non-engineered housing that is highly vulnerable to shaking. The region being the nation's capital, is the nerve centre for internal and external security, and managing of the national economy. Thus any disruptions, particularly by a large event, can have immense catastrophic consequences for the entire nation.

For initiating actions to mitigate perceived hazards from future earthquakes, the first steps are to identify and quantify the seismic hazard and the exposure and vulnerability of society to it. The most popular seismic hazard assessment method currently in use is PSHA (Probabilistic Seismic Hazard Assessment). It is based on the assumption of stationarity of seismicity and a Poisson model of earthquake occurrence. It thus provides a time-independent hazard assessment. The seismicity, however, is found to show clustering in space and time, a feature that is not reflected in the probabilistic seismic hazard model. For example, the probability of occurrence increases after large earthquakes when aftershocks follow. The Gutenberg Richter recurrence relation provides estimates of average recurrence times of earthquakes, which implies that following an earthquake of a particular magnitude, the probability of occurrence of an earthquake of a similar magnitude will tend to increase after the lapse of the return period.

The physical basis of expecting time-dependence of probability is Reid's well established elastic rebound theory of earthquake occurrence, wherein there is a preparatory phase of building up of strain that is released at the time of the earthquake. The probability of occurrence of an earthquake therefore increases with time as the strain build up increases. The time-predictable recurrence model of large earthquakes of Shimazaki and Nakata[6] is based on this theory, which is the basis of time-dependent seismic hazard estimates. Furthermore, the stress transfer from large earthquakes on neighbouring faults forms a feedback mechanism changing the probabilities[7].

A number of PSHA estimates of seismic hazard of the NCR are available[8–14]. These studies find that a PGA of about 0.15 g has a 10% probability of exceedance in 50 years. In the light of the theory of time-dependent hazard noted above, these estimates do not address the question: what is the probability of occurrence of a large damaging earthquake like the ones of 893 or 1720 at the present time? Is there a probability gain with elapse of time since the last event? For earthquake sources in the Himalaya seismic zone, considering the chances of occurring of a great earthquake there in the next 50 years, an estimate of seismic hazard based on time-predictable model of seismic hazard shows a 0.3 probability of experiencing a PGA of 0.2 g in NCR[15]. This is a probability 3 times higher than obtained from PSHA model, rendering the risk that much more serious.

In order to sharpen the hazard assessment of the region we need to consider the whole spectrum of processes as a system – the earthquake hazard system (EHS). We give below a partial list of the information defining various aspects of an earthquake system, that is needed and which is as yet not available in any measure for the NCR. Such an integrated programme will allow generating the information needed to analyse more incisively the EHS in NCR.

Any comprehensive approach must answer questions such as: what is the seismotectonic regime and what are the governing parameters of the same[16–19]? Can we define the strain generating systems and their characteristics[18–21]? What are the spatio-temporal characteristics of seismicity and how does it relate to seismic hazard[20,22]? What can palaeoseismic investigations tell us about recurrence rates and characteristic earthquakes[21,23]? Their relationship with tectonics and geological structure? How is the hydrological regime connected with seismiciy[24]? What information is being provided by the small earthquake activity – how far can we extrapolate from this information to the large earthquake regime[25,26]? What geological process has resulted in hot springs in the area and how is it related to the seismo-genesis in the region[24]? Can it provide any clues as to time-dependent changes of strain regime in terms of time dependent thermal, flow rate and compositional (e.g. radon content, etc.) anomalies? What is the detailed 3-d geological and geophysical structure of the region? What clues can the satellite data provide to understand the evolution of the seismogenic processes[27,28]? How can GPS (e.g., ref. 21) data come in to constrain the earthquake system? How can we generate a time-dependent seismic hazard estimate with respect to seismicity in NCR, etc? The references above are cited with the purpose of setting the horizon for developing the programme and are not comprehensive in any manner. Similar questions can be formulated in respect of Earthquake Risk System (ERS) to enable creating a programme that is as comprehensive and effective as it can get, to mitigate possible disastrous effects and efficient relief measures in case of such an eventuality. However, since the problems are highly inter-disciplinary, for successful achievement, involvement of groups of specialists is essential, which can distinguish between chaff and grain and produce a programme that has implementable goals and the best means to do it.

A well considered, over-arching science research plan to address the EHS and ERS for NCR brought to light by publishing in forums like *Current Science*, Internet Web Site of the DST, etc. will enable the science community as well as other interested elements to become familiar with the programme, participate in a debate, thereby contributing their ideas to enrich the programme further.

It is recognized that full information about the ongoing programmes is not available with the authors, nevertheless we note that, to the credit of the programme, in recent past successful investigations have been launched for earthquake hazard micro-zoning of the region using noise and earthquake records[12,13], PSHA[14], etc.

1. Srivastava, L. S. and Somayajulu, Proceedings of the III Symposium on Earthquake Engineering, Roorkee, 1966, pp. 417–422.
2. Srivastava, V. K. and Roy, A. K., Proceedings of the IV Congress of the International Association of Engineering Geology, 1982, vol. VII, pp. VIII.77–VIII.86.
3. Narula, P. L. *et al.* (eds), *Seismotectonic Atlas of India and its Environs*, Geological Survey of India, 2000.
4. Iyengar, R. N., *Curr. Sci.*, 2000, **78**, 568–574.
5. Tandon, A. N., *The Very Great Earthquake of August 15, 1950*, The Central Board of Geophysics, Govt of India, 1953, p. 89.
6. Shimazaki, K. and Nakata, T., *Geophys. Res. Lett.*, 1980, **7**, 279–283.
7. Harris, R. A., *J. Geophys. Res.*, 1998, **103**, 24347–24358.
8. Khattri, K. N., Rogers, A. M., Perkins, D. M. and Algermissen, S. T., *Tectonophysics*, 1984, **108**, 93–134.
9. Bhatia, S. C., Kumar, R. and Gupta, H. K., *Ann. Geophys.*, 1999, **42**, 1153–1164.
10. Basu, S. and Nigam, N. C., Proceedings of the World Conference on Earthquake Engineering, New Delhi, 1977, vol. 2, pp. 425–431.
11. Parvez, I. A., Panza, G. F., Gusev, A. A. and Vaccari, F., *Curr. Sci.*, 2002, **82**, 158–166; Parvez, I. A., Gusev, A. A., Panza, G. F. and Petukin, A. G., *Geophys. J. Int.*, 2001, **144**, 577–596; Parvez, I. A. and Ram, A., *Pure Appl. Geophys.*, 1999, **154**, 23–40.
12. Mukhopadhya, S., Pandey, Y. and Dharmaraju, R., *Curr. Sci.*, 2002, **82**, 877–881.
13. Pandey, Y., Dharmaraju, R., Chauhan, P. K. S. and Chidanand, B., Report, CBRI, Roorkee.
14. Iyengar, R. N. and Ghosh, S., Proceedings of the INAE National Seminar on Disaster Management and Mitigation, SERC, 2003, pp. 1–16.
15. Khattri, K. N., *Curr. Sci.*, 1999, **77**, 967–972; Khattri, K. N., *Himalayan Geol.*, 1999, **20**, 1–46.
16. Bak, P. and Tang, C., *J. Geophys. Res.*, **94**, 15635–15637.
17. Allegre, C. *et al.*, *PEPI*, 1995, **92**, 215–233.
18. Main, I., *Rev. Geophys.*, 1996, **34**, 433–462.
19. Ito, K., *Phys. Rev.*, 1995, **E52**, 3232–3233.
20. Bilham, R., Bendick, R. and Wallace, K., *Proc. Indian Acad. Sci.* (*Earth Planet. Sci.*), 2003, **112**, 315–329.
21. Bilham, R. and Gaur, V. K., *Curr. Sci.*, 2000, **79**, 1259–1269.
22. Brehem, D. J. and Braile, L. W., *BSSA*, 1998, **88**, 564–580.
23. Wyss, M. and Burford, R. O., USGS OFR, 1985, 85–754, 367–426; Wyss, M. and Burford, R. O., *Nature*, 1987, **329**, 323–325.
24. Sieh, K., Stuiver, M. and Brillinger, D., *J. Geophys. Res.*, 1989, **94**, 603–623.
25. Schwartz, D. P. and Coppersmith, K. J., *J. Geophys. Res.*, 1984, **89**, 5681–5696.
26. Johnson and McEvilly, T. E., *J. Geophys. Res.*, 1995, **100**, 12397–12950.
27. Singh, R. P., Bhoi, Sahoo, A. K., Raj, U. and Ravindran, S., *Curr. Sci.*, 2001, **81**, 162–164.
28. Dey, S. and Singh, R. P., *Nat. Hazards Earth Syst. Sci.*, 2003, **3**, 749–755.

K. N. KHATTRI[1]
DINESH KUMAR[2]
IRENE SARKAR[3]
SAGARIKA MUKHOPADHYAY[4]
V. SRIRAM[5]

[1]100, Rajendra Nagar,
Dehradun 248 001, India
[2]Department of Earth Science,
Kurukshetra University,
Kurukshetra 136 119, India
[3]Faculty of Engineering and Technology,
Modi Institute of Technology and Science,
Lakshamangarh 332 311, India
[4]Department of Earth Science,
Indian Institute of Technology,
Roorkee 247 667, India
[5]Wadia Institute of Himalayan Geology,
Dehradun 248 001, India
**e-mail: knkhattri@yahoo.com*